



ARCHAEOMETALLURGICAL RECORD AS TOOL TO PRESERVE ARCHITECTURAL HERITAGE INFORMATION IN MALAGA, SPAIN

El registro arqueometalúrgico como herramienta para conservar la información del patrimonio arquitectónico en Málaga, España

MARCO HERNÁNDEZ-ESCAMPA ¹, DANIEL BARRERA-FERNÁNDEZ ², CARMINA MENCHACA-CAMPOS³, JORGE URUCHURTU-CHAVARÍN ⁴

¹ Universidad de Sevilla, España

² Universidad de Sevilla, España

³ CIICAp-IICBA, Universidad Autónoma del Estado de Morelos, México

⁴ CIICAp-IICBA, Universidad Autónoma del Estado de Morelos, México

KEYWORDS

Archaeometry
Archaeometallurgy
Archaeology
Heritage
Urban planning
Tourism
Human geography

ABSTRACT

This work approaches views on the preservation of industrial housing heritage in Malaga, Spain, and the pressure caused by its recent urban renovation. The aims of the research include geographic space analysis and assessing how archaeological recording and archaeometry, specifically archaeometallurgy, can contribute to the preservation of information about structures and materials that continuously disappear from urban contexts. The results constitute an initial beginning to expand a comparative archaeological database for the city. The ideas and procedures presented here are expected to provide some guidance for generating further research from urban, architectural, archaeological, and geographical perspectives.

PALABRAS CLAVE

Arqueometría
Arqueometalurgia
Arqueología
Patrimonio
Planeamiento urbano
Turismo
Geografía humana

RESUMEN

Este trabajo aborda visiones sobre la conservación del patrimonio industrial de la vivienda en Málaga, España, y la presión provocada por su renovación urbana. Los objetivos incluyen el análisis del espacio geográfico y evaluar cómo el registro arqueológico y la arqueometría, específicamente la arqueometalurgia, pueden contribuir a la preservación de información sobre estructuras y materiales que desaparecen de los contextos urbanos. Los resultados constituyen un comienzo para elaborar una base de datos arqueológicos comparativos para la ciudad. Se espera que las ideas y los procedimientos brinden una guía para generar más investigaciones desde perspectivas urbanas, arquitectónicas, arqueológicas y geográficas.

Recibido: 14/ 07 / 2022

Aceptado: 27/ 09 / 2022

1. Introduction

Societies have different tools that vary over time to preserve their material heritage, including architecture. In the case of western contemporary societies, it is widely acknowledged that the initial attempts to socialize and standardize the heritage conservation discourse can be traced to the Athens Charter (1931). Following the previous positivism of the nineteenth century, in this document and its report from 1933, the historic monument was conceived as a single entity confined to its own materiality. In some way, this conservation tradition highlighted the quality of construction, as well as less tangible aspects such as beauty and antiquity (Choi, 2012). The consequence of this conceptualization implied in practice that those buildings acknowledged as monuments tended to be related with upper classes and therefore with power. In this way, cathedrals, palaces, and major buildings earned the attention of professionals and people in general.

As time passed, new proposals emerged. Following the diverse charters and recommendations, the notion of isolated monuments led to sets of monuments and tangible values were complemented with social and more inclusive views on what constitutes architectural heritage, all of it combined with an increasing concern in sustainability (Kanashiro, 2004; Niglio, 2009). Therefore, in terms of heritage conservation, there is a historical tendency to emphasize the importance of the monument in the sociocultural context of the sets and to include the active participation of people during the process. In any case, the foundational idea of a monument somehow prevailed in some practices leading to undervaluation of architectural elements considered of lesser relevance, specifically housing. This is particularly notorious with respect to recent architecture, which in some cases does not fit any heritage classification and, at the same time, is subject to destructive pressures (Moss, 2016). Still, in some cases, houses constitute the predominant elements of some appreciated contexts. Thus, important works on housing have been performed, especially studies on vernacular architecture, once again usually stressing sustainability (Mileto *et al.*, 2014; Ashish Ganju, 2016; Olukoya, 2021).

From an archaeological point of view, concentrating focus on material culture produced by elite social segments implies an interpretive distortion of past societies, undermining the inclusive view required to understand culture integrally. In fact, a great amount of data on daily life can be inferred from domestic contexts (Steadman, 1996; Carpenter & Prentiss, 2022; Carter, 2022). When seen as this, homes represent not only the visual or volumetric connective tissue in historical contexts. Instead, their distribution patterns, constructive details, and internal spatial design constitute valuable information sources. Aware that valorization and scientific study of housing heritage have achieved good results in other academic works, it is still possible to state that archaeological study of industrial era housing, considered here as the nineteenth century and onward, is still an ongoing process.

Another relevant concept regarding housing heritage is related to the fact that individual houses might increase their scientific interest when conceived in groups. In this sense, the notion of a neighborhood should be emphasized. All urban settlements consist of neighborhoods, and these systems, especially prior to modern urban planning, constitute the material culture that orders space and a multitude, if not all, of the social activities of a given society. In fact, it has been claimed that the social decisions of small groups reflect the structure of neighborhoods and the city overall, and this also produces spontaneous order. This process leads to social change as negotiations between individuals occur (Graeber & Wengrow, 2021). This explanatory proposal about social change might relate to previous statements such as the role of individual agency in cultural change (Hodder & Renfrew, 1982), yet it contributes to the linkage of the process to an architectural or urban space. In any case, the conception of neighborhoods as complex entities composed of both material and intangible elements has led to increased interest and its defense in heritage terms (Pendlebury *et al.*, 2016; Angelcos & Mendez, 2017).

Historic cities are subject to constant pressure that causes social and architectural changes. One of the most clearly identifiable pressures of these is tourism activity. In many cases, gentrification processes can be detected in these circumstances. It is common for houses to lose their original function, now harboring new activities such as lodging, restaurants, and stores (García Bujalance *et al.*, 2020; Lees, 2012), or sometimes they are just demolished and replaced by more recent structures. During this transformation, a wide range of interventions alter these buildings. Sometimes, the original spatial quality of the houses is preserved, and the changes are minor and clearly reversible. However, it is far more common for major modifications to houses and only their façades to be left to meet the legislative demands of urban space, which rarely include internal spatial design (Rosique Cañas, 2017). In the case of Andalusia, Spain, usually the façade and the first intercolumnal space are protected. It can be assumed that the implicit inferior hierarchy of houses in comparison to major buildings is what allows this process, since people can think that nonrelevant edifications are altered, and desired immediate economic benefits are obtained.

Despite current and future efforts to preserve the heritage of housing in cities, it is expected that existing pressures will continue to cause a decline in architectural and archaeological assets. At the same time, the concept of loss in heritage preservation has also been questioned and even proposed as an integral part of the entire process (Holtorf, 2015; DeSilvey & Harrison, 2020). In fact, it is not possible to establish complete protection for historic housing design because it evolves over time as new social requirements arise continuously. In addition,

well-planned interventions might insert contemporary architecture into historic contexts, adding to the aesthetic values of a given context.

Although relativization of housing heritage loss has a point, especially from the perspective of social anthropology and its inherent cultural change approach, from an archaeological perspective, the opportunity to obtain information from the material culture is usually lost once the artifacts or structures disappear. Digitalization of existing heritage and virtual reconstruction offer the opportunity to record and analyze material culture to determine whether there is or not any possibility of disappearance (Dell'Unto *et al.*, 2013; Aburadaman *et al.*, 2021). Although these modern techniques oriented to spatial analysis have a higher value, they can be complemented with archaeometric characterization of materials. Eventually, the data obtained can become a data base to preserve physical and chemical information that can only be recovered from the actual archaeological materials.

There may not be a single answer to conservation of housing heritage. However, some housing contexts have suffered a clear reduction, leading to the transformation of entire neighborhoods due to tourist pressure. Thus, proposals directed at registering data at least before the disappearance of the materials might be useful. To explore this possibility, this study was conducted in Malaga, Spain, due to its prestige as the capital of a widely known tourist region where problems such as housing loss and gentrification are, in fact, implied in urban and economic dynamics. Malaga is located on the Mediterranean coast of Spain. It is the sixth largest city in the country and the second in Andalusia, with around 580,000 inhabitants (Instituto de Estadística y Cartografía de Andalucía, 2022). The origins of the city can be traced back to the eighth century BC, when a Phoenician and Punic settlement was established. The Romans and Muslims left their legacy until the city was conquered by the Catholic Kings in 1487. In modern times, the city attracted a mercantile bourgeoisie linked to maritime trade, who consolidated its industrial position (Pino, 2020). However, as in many other cases in Europe, the industrial port lost competitiveness due to factory relocation and the obsolescence of the port facilities. To adapt to this challenge, the city based its economy on services and especially the city center and the port were reconverted into a destination for urban cultural tourism, offering a complementary offer to the mature destination of the Costa del Sol, specialized in sun and sand tourism (Barrera-Fernández, 2021). Today, the city is known for attracting cruise ship passengers, around 40 thousand annually, being the third largest port of this kind in mainland Spain after Barcelona and Cadiz (Observatorio del Transporte y la Logística en España, 2022), and its airport attracts around 6 million passengers annually, being the fourth in Spain after Madrid, Barcelona, and Mallorca (Aeropuertos Españoles y Navegación Aérea, 2022). The flagship of the Malaga tourist strategy has been the opening of several museums linked to world-renowned artists and brands, such as the Picasso Museum, Carmen Thyssen Museum, and the Pompidou Museum, which has made the city considered a cultural hub (Vora, 2016).

An archaeological and architecturally relevant industrial period neighborhood was detected in the city, and within it a case study of housing transformation has been analyzed in depth. Archaeometry and, more specifically, archaeometallurgy techniques were employed to exemplify their use as tools of potential data recollection. This experience is expected to be a source of partial answers to the complex question of studying and conserving heritage housing.

2. Objectives

The main objective of this work is to initiate the evaluation of a housing heritage record in Malaga, before disappearance or transformation, and from an archaeological and geographical point of view. To fulfill such a goal, secondary objectives appear as follows:

1. To elaborate both a context and a reflection on the importance of the housing heritage in Malaga and the causes of its loss in the urban space.
2. To locate by spatial analysis the heritage category under study and evaluate the extent of preservation in urban space.
3. To explore the possibilities of information rescue through archaeological record and archaeometry, exemplified here mainly with archaeometallurgical materials, as a first step to palliate the irreversible diminishing of the context. This through a case study.

3. Methods

The methods used in this research included:

1. Analysis of documentary sources and cartography. The historic center was analyzed in this work. The literature was used to create a critical discourse analysis and a reference frame on Malaga, its heritage protection policies, and its housing heritage. Cartography was used to identify the period when historical houses started to be replaced by taller buildings due to tourist pressure and land speculation, as well as to establish possible concentrations of housing heritage in the studied area. The relevant maps analyzed included:

1.1. The 1892 city plan (Cerda, 1892) was considered as a main reference because it was reasonable to assume that the late nineteenth century chart could depict full existing neighborhoods prior to the recent and massive urban transformations.

1.2. The cartographic work developed by Ozomek (2011) was taken as a base to identify the degree of heritage loss in the different areas of the historic center. This work covers since the 1960s, when the first modern construction boom took place in the city, until the 2010s, coinciding with a recent construction boom still going on.

1.3. The cartography included in the urban plans protecting historic neighborhoods in Malaga (Malaga City Council, 1999; 2000; 2011) was also reviewed to identify the clusters of single-family houses that still exist in the city center.

As a result of this cartographic analysis, the authors created a map identifying the major remnants of the housing heritage concentrations in the center of Malaga.

2. Archaeological survey. One of the remaining housing areas located in the northern portion of the study area was chosen because of its size and proximity to the Cervantes Theatre, one of the points of interest in the city. Through direct observation in the field, a photographic record of the housing heritage was produced assessing the conservation state and overall urban conditions of the remnant. During this survey, a case study was identified, being the criterion for choosing it the access to materials. The site consisted of a nineteenth century house with an ongoing restoration process, which produced discard of original materials. It is pertinent to mention that the house was found to be currently not listed under any heritage protection legislation.

3. Architectural analysis. A more detailed description of the house was obtained, comparing the previous stages of the building and the final result of the restoration.

4. Archaeometry. Discard materials were collected with permission from the building owner, such as tiles, bricks, and pieces of balcony railings. The latter were subjected to archaeometallurgical characterization to illustrate the potential of archaeological record under circumstances of heritage transformation. A brick wall sample was also studied as an example of the analysis of other types of materials. The analyzed materials belong to the original constructive phase of the building. Techniques included metallography, spark source mass spectroscopy to obtain the elemental chemical composition, scanning electron microscope (SEM and EDS) to obtain the morphology and semiquantitative chemical composition of all studied materials, and X-ray (X-R) diffraction technique to identify crystalline compounds such as oxides in the metallic surfaces or constitutive crystals of the brick.

4. Results

4.1. Evolution of heritage protection in Malaga

In the case of Malaga, the protection of urban heritage was not a priority until the last decades of the twentieth century. Even tourist guides reflected the lack of interest of the city in this issue: 'This city, commercial par excellence, has seen with indifference the disappearance of the monuments left by its dominators, the works by Arabs, and even the churches raised by those who repopulated it, but it has in turn an indescribable liveliness and does not lack of modern buildings worthy of the admiration of the traveler' (Valverde y Álvarez, 1888, p. 448). However, the city started to protect its heritage in local laws, especially focusing on the aesthetic interest of public furniture (Malaga City Council, 1872). In 1876, façades were protected in a general way (Malaga City Council, 1876), and in 1884 it was established that owners were responsible for keeping their buildings in good condition (Malaga City Council, 1878). These early attempts were not enough to stop the deep remodeling of the city center brought about by development plans in the late nineteenth and early twentieth century, which were focused on opening streets and creating new public spaces in order to improve public health and to increase the appeal of the city (Malaga City Council, 1924; 1929). Many historic buildings were lost, but on the other hand, the new spaces are today the main representative areas of the city, as well as the most visited by tourists.

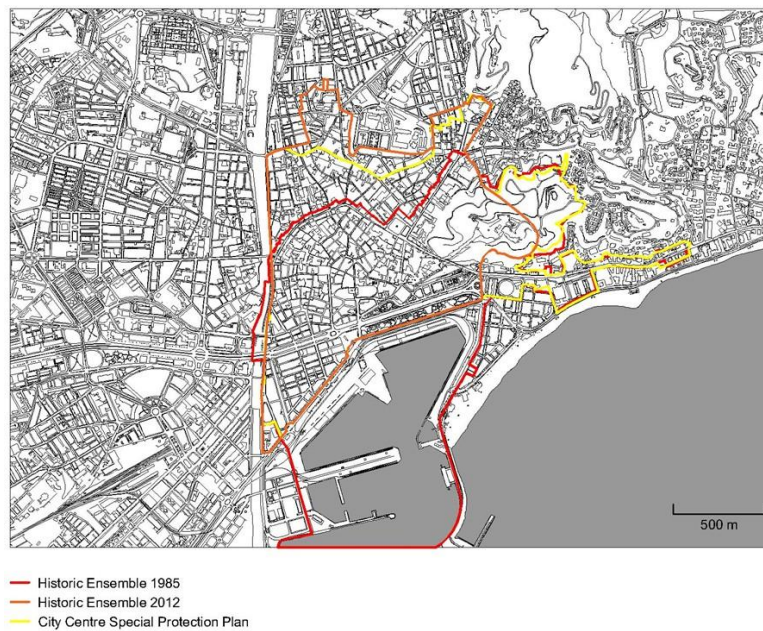
Between the 1930s and 1950s, the efforts made by José González Edo to protect the built heritage were remarkable, often with the opposition of the City Council. Although many of his ideas were not implemented, some of them inspired the Local Plan of 1983. Thanks to his work as a member of the Real Academia de Bellas Artes de San Fernando, a selected group of monuments were listed individually, for some of them a buffer zone was established, and a first Conjunto Histórico (Historic Ensemble) was designated. However, the City Council did not implement it due to the limitations to construction permits that would have entailed (Malaga City Council, 1948; González Edo, 1970). At this time, the Alcazaba, the Arab castle, was saved from being demolished. After the Spanish Civil War, restoring this monument became a priority for political reasons and due to its interest in attracting tourists (González Edo, 1944). However, its restoration received considerable criticism for its lack of rigor (Ortiz Barili, 1945). Between the 1950s and 1970s, there was strong construction activity. Works had limited controls and, as a result, many traditional houses were replaced by apartment buildings, and complete neighborhoods lost their historic urban fabric to give way to wide avenues flanked by towers (Caballero Monrós, 1967).

Restoration of democracy brought about a new legal framework. It coincided with an economic crisis that made large developments less profitable. The process for designating a new Historic Ensemble was initiated, and, without coordination, new Special Plans including heritage protection policies were approved, following international agreements on heritage of the moment. These documents incorporated a concern for social aspects and a mix of uses. Furthermore, new heritage assets were considered, such as buildings of townscape merit, the urban layout, the landscape, and natural spaces (Malaga City Council, 1983). However, these innovative ideas at their time became diluted in the implementation of the plans.

4.2. Current heritage protection policies

The city center concentrates most of the buildings and areas deemed to have heritage value. A part of the city center was designated Historic Ensemble in 1985 (Dirección General de Bellas Artes, 1985). The limits of the designated area were modified in 2012, which meant the exclusion of some areas (the port and the river), the inclusion of other areas north of the ancient walled city, and the alteration of the eastern limits. The designation of a Historic Ensemble entails several controls and restrictions within its boundaries, which are complemented by another figure of protection: the City Center Special Plan (Malaga City Council, 1992) (Figure 1). The latter is the responsibility of the City Council and is associated with a detailed list of built elements subject to heritage protection. In Malaga, the delimitation of the City Center Special Plan coincides neither with the former Historic Ensemble nor with the current one. This lack of coincidence entails that some historic areas of the city center are under control by the Andalusian and local heritage authorities, while in other areas only a few restrictions apply or none of them.

Figure 1. Previous and current limits of the Historic Ensemble and the area included in the Special Protection Plan



Source: the authors.

In the central area, 45 assets are included on the Andalusian Heritage List (Andalusian Government, 2022). Most of them are Bienes de Interés Cultural (assets deemed of having cultural interest; it is the highest grade), in the category of monuments. Among Bienes de Catalogación General (second grade), examples of modern, industrial, and residential assets can be found, although these elements are also included in other categories. Bienes de Interés Cultural have a buffer zone in most cases, although they do not guarantee greater control of interventions in practice. The City Center Special Plan has its own list of protected assets, including buildings, special public spaces, archaeological remains, murals, and outstanding trees. For buildings, there are two levels of protection: integral protection and architectural protection. Integral protection means the preservation of the whole building with its architectural features, shape, outline, and all the characteristics that make it special. In structures having architectural protection, only specific parts of the building must be preserved; this group is subdivided into three levels, according to the relevance of the extension of the protection: grade I, grade II, and scenic protection. The archaeological heritage list includes mostly underground remains already found and to be unearthed during future interventions.

4.3. Recent transformations under tourist pressure

Since the 1990s, Malaga has specialized in the urban cultural segment due to its good communications, the ability to attract cruise ships, and the presence of a more relevant built heritage and cultural offer than in other surrounding destinations. The growth of cultural offer paralleled the bidding process for being designated European Capital of Culture 2016. Tourism was seen as a way to address economic decline and mitigate the loss of urban activities, especially in the port. Malaga received 1,410,171 tourists in 2019, the last year before the outbreak of COVID-19 and the length of stay was 2 days on average (Instituto Nacional de Estadística, 2022). As mentioned above, the city has made an effort to increase the number of cultural tourists through the opening of new museums. Among the most visited ones are the Contemporary Art Center (130,910 visitors), Picasso Museum (703,807 visitors), Picasso's Birthplace (121,406 visitors), Carmen Thyssen Museum (170,323 visitors), and Pompidou Museum (177,491 visitors). Other main tourist attractions are monuments such as Gibralfaro Castle (547,198 visitors) Alcazaba (711,067 visitors), and the Cathedral (483,707 visitors) (Fundación CIEDES, 2022). Some sections of the port became redundant in the 1990s as a result of the relocation of activities to facilities located in other cities, and it has been subject to a deep reconversion into an open-air shopping center. In addition, new facilities have been added to welcome larger cruise ships, including a passenger terminal. As a result of these interventions, Malaga received 288 cruises and 40,172 cruise passengers in 2019 (Málagaport, 2022).

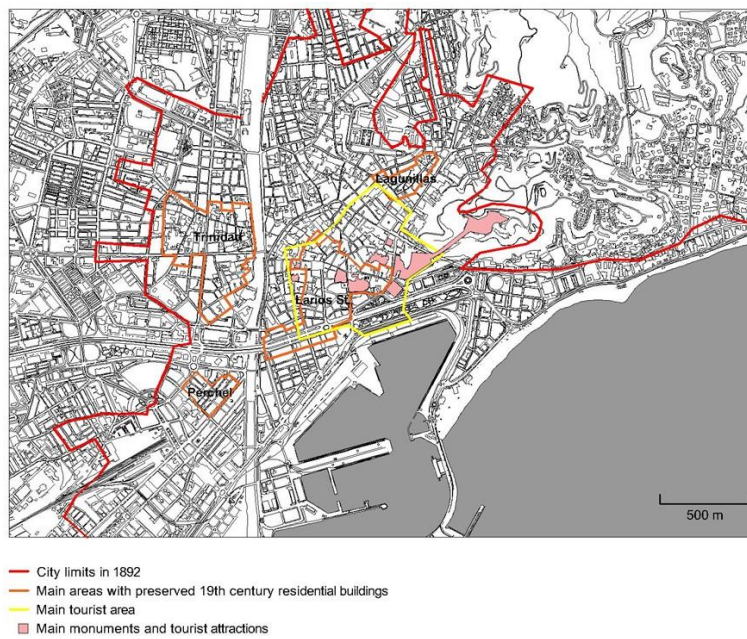
4.4. Cartographic analysis

The 1892 city plan (Cerdeña, 1892) was useful in identifying the city limits at that time, the existing residential neighborhoods, and the planned extension of the city, which was developed in the following decades. The cartographic work developed by Ozomek (2011) focused on the area located within the limits of the medieval Muslim wall. The map identifies which historic buildings have been knocked down, which ones have been severely modified, and only the façade remains, which of them are in ruins, and the degree of protection of the remaining ones. It shows that the main preserved area in this sector is located around Larios Street, Alameda Principal, and the Cathedral. From the cartography included in the urban plans, other residential areas outside the medieval wall and from the nineteenth century that are still preserved were identified, such as Trinidad and Perchel.

Since this work deals with tourist pressure, the limits of the main tourist area were identified, according to previous work that analyzed tourist activities and services in the city (Barrera-Fernández & Hernández-Escampa, 2017).

Figure 2 shows the results of the spatial analysis, including the extension of the city in 1892. It is possible to consider that the late nineteenth century was the last epoch during which functional neighborhoods extended throughout the city before recent substitutions and major urban changes occurred in the city. Four main housing remnants still survive, namely Larios Street, Trinidad, Perchel, and Lagunillas. Of these, two of them (Perchel and Trinidad) still exist because they are not directly related to tourist pressure, although they might be influenced by land speculation anyway. Trinidad has been subject to a large substitution of residential housing, where only a few scattered elements have survived. Larios Street constitutes a particular case because it lodged the elite class of the city from the beginning, with multistory buildings already built in the nineteenth and early twentieth centuries. Since this area has been completely gentrified, there is no longer housing activity for local residents. Instead, it is devoted to tourism and commercial businesses. In any case, this work does not focus on elite-related material culture. As a consequence, the detected area that fits the relationship between the disappearance of housing heritage and the pressure to tourism is the Lagunillas neighborhood, located north of the Plaza de la Merced.

Figure 2. City limits in the late nineteenth century, main area with preserved nineteenth century housing, and main tourist area



Source: the authors.

4.5. Lagunillas neighborhood and housing case study

The Lagunillas neighborhood is within the limits of the Historic Ensemble and the City Center Special Plan. Its particular location close to Picasso’s Birthplace and Cervantes Theatre has made it an area of opportunity for investors. As in many other parts of the city center, a combination of degradation, speculation, and lack of attention from the public administration caused the degradation and loss of population of the area. Many houses were abandoned, some of them were left in ruin, and others finally collapsed. Furthermore, a regeneration project led by the Andalusian Government failed when a number of houses had been purchased from their previous owners, leaving them empty and in a legal limbo. The future of these houses has not been decided yet; some of them are expected to be returned to their previous owners, while other ones are supposed to be kept by the public administration and included in a regeneration plan not yet defined.

In this difficult context, some entrepreneurs have bought abandoned buildings to convert them into hostels, boutique hotels, and apartments. The current state of conservation of nineteenth century housing in the Lagunillas neighborhood covers a wide range of situations, including demolished buildings that left an empty plot, abandoned houses, and restored buildings with two main uses: residential and tourist apartments, the latter the current prominent use of recently restored houses (Figure 3).

Figure 3. a) empty plot after demolition, b) abandoned building, c) restored building turned into tourist apartments



Source: the authors.

The house located at 29, Cobertizo del Conde Street, became the case study for this work. It has two floors. The original house covered only the first half of the plot, leaving the second half as a courtyard. It was built in 1890 in regionalist Andalusian style (Figure 4). Some of the most characteristic architectural features are the columns made of bricks, the flat tiles on the roof typical of this period and showing an early industrialization of building materials, the hydraulic floor and the green and white tile pipes. In the 1950s, the house was renovated. It extended towards the courtyard, leaving just one third of the original unbuilt. The interior was modified, including the construction of walls, the replacement of parts of the floor, the installation of a bathroom, and a garage. In 2015-2022, the house was intervened again. As seen in Figure 7, this time the renovation consisted of modifying the interior distribution, replacing windows, doors, plumbing, and electricity. The volume of the 1950s was not altered and some original parts of the 1890s remained, such as foundations, columns, perimeter walls, stairs, façade, balconies, railings, and roof, including wood beams and roof tiles (Figures 4 and 5). It is important to note that the house is not listed. The materials used in this work were obtained from abandoned items with the owner's permission at the moment of transformation of the architectural and archaeological context.

Figure 4. Façade of the case study



Source: the authors.

Figure 5. House plans showing the original 1890 extension and the alterations in the 1950s and in 2015-2022



Source: the authors.

4.6. Archaeometallurgical record

As already stated, materials for this work were obtained from architectural renovation discards executed in the nineteenth century house. A balcony railing and a brick wall were sampled, both from the initial phase of the house. Regarding the railing, a bar was separated from which three transverse section coupons were obtained using a disk cutting machine. Coupon number 1 was used for spark source mass spectroscopy, coupon number 2 was embedded in Bakelite and polished with 180, 320, 400, 600, 1200, 2000, and 4000 papers on the metallographic polisher as preparation for metallographic analysis, and coupon number 3 was analyzed using a scanning electron microscope.

The composition of coupon number 1 was obtained by spark emission spectrometry, the main results shown in Table 1.

Table 1. Chemical composition obtained by spark mass spectroscopy for coupon 1

	Carbon (C)	Silicon (Si)	Manganese (Mn)	Phosphorus (P)	Sulfur (S)	Iron (Fe) & traces
1	4.112	1.353	0.516	0.589	0.002	Rest
2	3.901	1.123	0.845	0.512	0.001	Rest
3	3.872	1.004	0.972	0.466	0.001	Rest
Average	3.962	1.160	0.778	0.522	0.001	93.577

Source: the authors.

Metallographic microscopy provided a resolution of up to 500 X, and the coupon was observed before and after etching with Nital. Figure 6 shows the highest resolution obtained after etching.

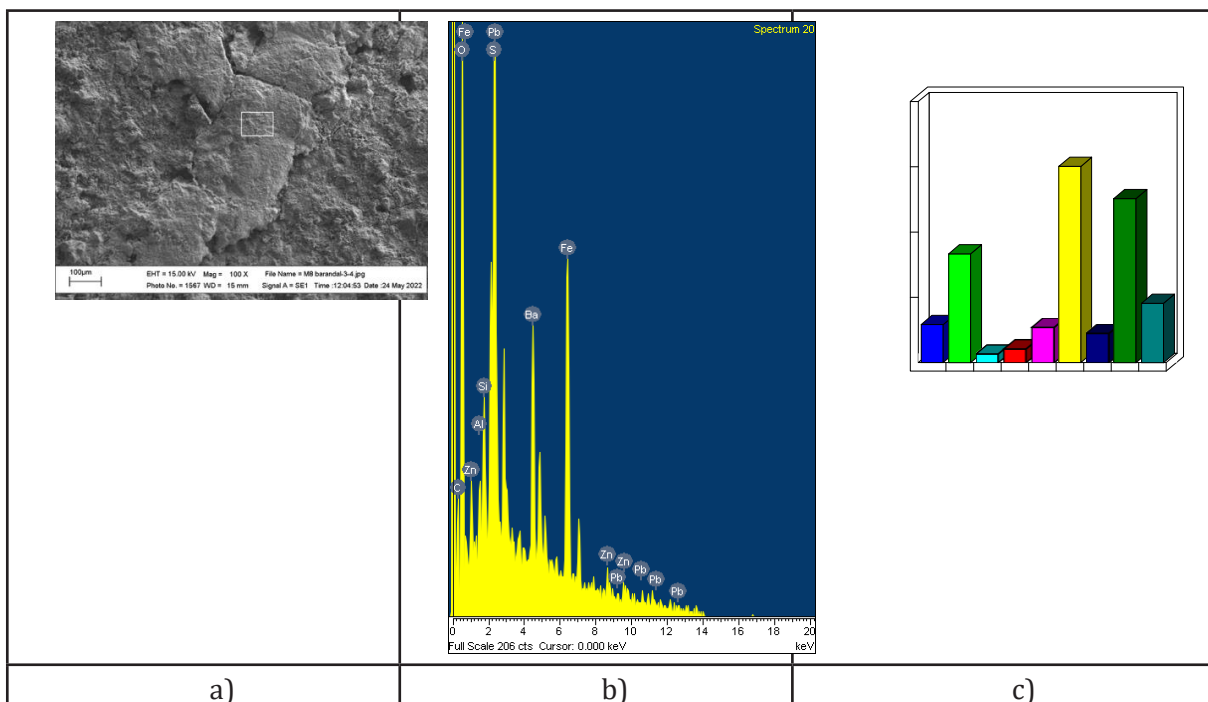
Figure 6. Metallography of coupon 2 showing graphite flakes embedded in a ferritic matrix, proper of a gray cast iron. 500X



Source: Hernández-Escampa, Barrera-Fernández, Menchaca-Campos & Uruchurtu-Chavarín (2022, May 22).

Scanning electron microscope (SEM and EDS) was used to analyze the corroded surface of coupon 3 to obtain morphology and semiquantitative elemental chemical composition (Figure 7). The SEM micrograph presents corrosion products on the metal surface showing heterogeneous structures with multiple cracks and voids. The EDS yielded different elements, including iron as a base metal and other metal impurities, most probably in the form of oxides, as well as less common barium and lead, which are not present in the metallic core according to the spark mass spectroscopy results, which suggests that they correspond to a protective varnish or coating.

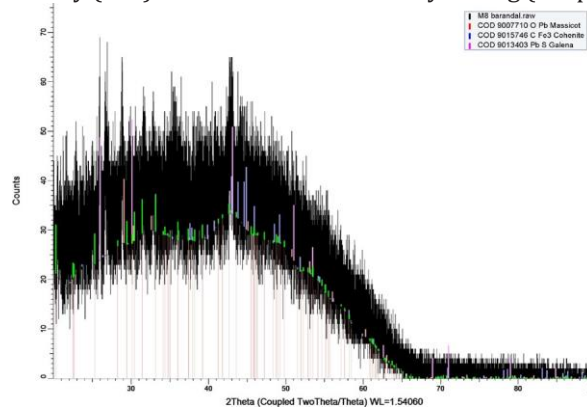
Figure 7. Coupon 3. a) SEM micrograph, b) EDS analysis, and c) Elemental content



Source: the authors.

X-ray (X-R) diffraction analysis (Figure 8) for the balcony railing (coupon 2) shows the existence of a metal base. Additionally, lead oxides and sulfur compounds were present, and this may be due to possible remains of the coating or varnish applied in the past, which normally contains lead compounds in its composition. Crystalline species detected include massicot, cohenite, and galena.

Figure 8. X-ray (X-R) diffraction of the balcony railing (coupon 2)

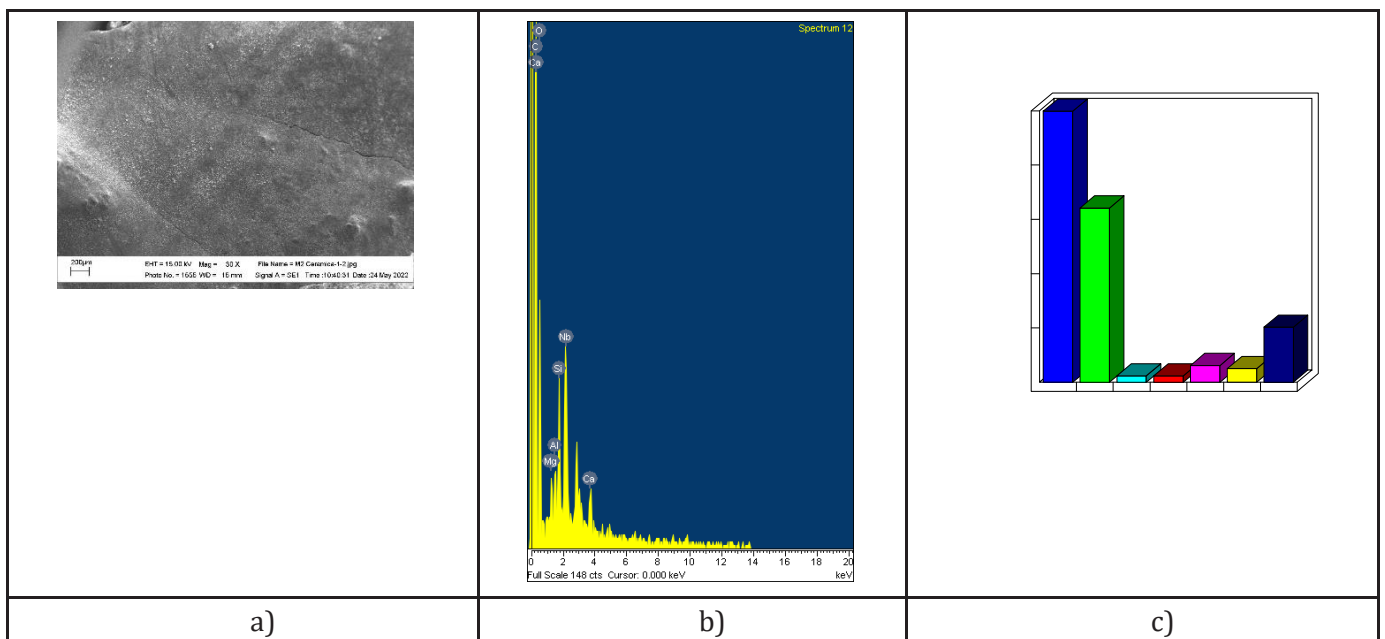


Source: the authors.

4.7. Other materials

A brick sample was analyzed using a scanning electron microscope. In this case, the core material was studied. Figure 9 shows the morphology of the ceramic material with a slightly rough surface, containing some dust-like particles. When analyzed for chemical composition, the surface showed the presence of elements such as Carbon (C) and Oxygen (O) that could represent oxides and carbonates, as well as other elements such as aluminum silicates and Niobium (Nb), which were not expected to be detected.

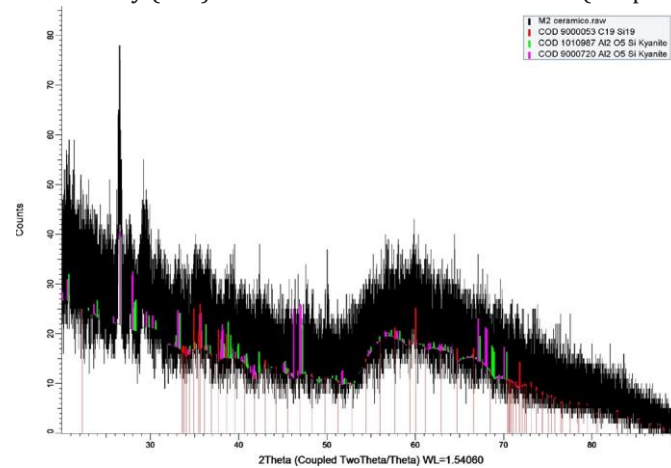
Figure 9. Ceramic brick wall (coupon 3). a) SEM micrograph, b) EDS analysis, and c) Elemental content



Source: the authors.

X-ray (X-R) diffraction (Figure 10) for the piece of ceramic (coupon 3) shows mainly aluminum silicates, especially Kyanite ($Al_2H_6O_5Si$), common for these ceramic elements of the age period. These corroborate the findings observed in the SEM and EDS analysis.

Figure 10. X-ray (X-R) diffraction of brick wall ceramic (coupon 3)



Source: the authors.

5. Discussion

5.1. Situation of the housing heritage in Malaga

Currently, the increase in the number of tourists puts pressure on the historic city to replace existing activities by other more profitable ones. As a result, in some sectors of the historic city, a monofunctional area has been created, where museums, hotels, restaurants and specialized shops have the leading role. In many cases, tourist activities have been inserted at the expense of heritage buildings, especially housing. Sometimes, museums have been built disregarding the context, as in the case of the historic neighborhood of La Coracha, which was knocked down and would have been a tourist reference for visitors today. In other cases, museums have not only occupied a representative building, but they have also implied the replacement of the blocks around, like the Picasso and Carmen Thyssen museums. In the construction of hotels, a common process has been to replace buildings with only the historic façade.

As found through analysis of the literature, the transformation of the historic city of Malaga to attract a larger number of tourists coincided with a boom in construction. Public administrations facilitated building initiatives by relaxing restrictions affecting protected buildings. As a result, a systematic disappearance of the heritage occurred. The particularities of this period were the imitation of historic styles and the erection of new buildings behind preserved historic façades. Historic layouts were lost and new facilities were created without respecting the scale and character of the area. Furthermore, many buildings deemed to have heritage value were destroyed, including many examples listed by the City Council. High prices encouraged business expectations, and when the bubble burst, many plots and buildings remained empty and neglected. This is the context of the neighborhood where the study case is located.

Following the results of the cartography and spatial analysis, it is possible to determine that the extent of the disappearance of the original neighborhoods in Malaga is considerable, but there are some remnants in different conservation situations. At least, some areas within such remnants could be identified for special preservation to leave some kind of architectural and archaeological print of this specific period in the urban development of the city.

The housing case shows some of the processes described in this work concerning the preservation of façades but not of the whole original spatial structure. On the other hand, its renovation to continue its housing function can be understood as a good practice for urban preservation. It is highly noticeable that this house and, assumably, many others in the Lagunillas neighborhood are not listed under any heritage protection, which allows easy access for land speculation processes.

5.2. Archaeometallurgy analysis

Regarding the archaeometallurgy of the balcony railing, the spark emission spectroscopy analysis shows a high content of Carbon (C), Manganese (Mn) and Phosphorus (P), confirming that the sample is clearly a kind of iron, as expected, and not a steel. All the metallographic results obtained showed a consistent microstructural pattern consisting of graphite flakes embedded into a ferritic matrix, where visible. Following the ASTM A247-16a (ASTM, 2022), this corresponds to the graphite type VII and B distribution, the proper form of gray cast iron. With regard

to the vast size of the flakes between 40 and 80 μm , this cast belongs to class 6. All findings are consistent with nineteenth century grey cast iron.

In relation to the manufacturing process, this result is obtained after reaching temperatures of about 1,200° C followed by slow cooling. Under such conditions, there is a tendency for Iron (Fe) to react with Carbon (C), forming Iron Carbide (Fe_3C). To avoid such loss of metallic Iron (Fe) substances, especially Silicon (Si) between 1 and 3% and Phosphorus (P), were added as graphitizers and hence, the presence of flakes in the intergranular spaces. As already shown by spark mass spectroscopy, the amount of Carbon (C) stays between 2.5 and 4%, and both Silicon (Si) and Phosphorus (P) are also detected (Collini *et al.*, 2008). However, this kind of material shows good fluency and is therefore appropriate for casting; however. It shows low tensile capacity and presents a fracture beyond the traction efforts of 15 Kg/mm². As a result, it is often used in non-structural architectural elements as is the case here.

Scanning electron microscope (SEM and EDS) showed a basically compact but heterogeneous morphology of corrosion products with some cracks. Regarding the chemical composition, the presence of Barium (Ba) and Lead (Pb) suggests that the material was treated to protect the metallic core as it was done in other metallic artifacts of the time and possibly also to give a desired look (General-Toro *et al.*, 2021). Otherwise, the chemical elements are coherent with the metallic Iron (Fe) and Carbon (C) core, while Silicon (Si) and Aluminium (Al) respond to dust, and Sulfur (S) and Oxygen (O) to atmospheric pollution and corrosion, even when Sulfur (S) is also found in the core. Further analysis is required to clarify the exact surface treatment; however, a hypothesis following X-ray (X-R) diffraction results could be the use of galena, which can be further developed into massicot by oxidation. All this combined or not with the better known and more usual minimum treatment. It becomes clear that these findings depict human technological action and knowledge to achieve a given specific goal, all relevant archaeological information. More recent coatings, such as paint, might also have enriched the surface, for example, with Lead (Pb).

5.3. Other materials

Brick analysis was initially just proposed as an example of analysis of materials different from metals. However, the presence of Niobium (Nb) in the material constitutes a potentially relevant finding. Niobium (Nb) is a rare element, and it could be correlated with specific deposits in the area, which must also be rich in Kyanite ($\text{Al}_2\text{H}_6\text{O}_5\text{Si}$) as demonstrated by the X-ray (X-R) diffraction results. Even when further studies are needed, this already becomes a geological clue and it might yield information about provenance and even commerce. Once again, as in the case of metal coatings explained above, archaeometry, through the characterization of materials, reveals archaeological information. It is possible to state that this couple of findings prove the point of the need to further increase the detailed analysis of materials from an industrial epoch, a big task yet to be performed from the archaeological and heritage points of view in Malaga.

6. Conclusions

The housing heritage in Malaga suffers a constant decline, to a noticeable extent, due to tourist pressure and the consequent land speculation. The late nineteenth and early twentieth centuries became the last period where historic houses still performed their major function as a material cultural seat of local social relationships. As the archaeological context is lost, so is the inherent social information. The historic center still houses some urban sections with valuable housing in different conservation states, especially on the outskirts, and sometimes related to the current degraded environments. Even when preservation policies exist, more actions are required to identify and effectively protect this kind of heritage. The sole fact that the case of study is not listed shows that this challenge persists.

Even when it is granted that modern pressures will continue to deploy the city from its industrial period housing contexts, archaeology and other disciplines can propose recording strategies to preserve the information to some extent, as shown in this work. While architecture can contribute with a graphic record and geography with spatial analysis, archaeology can provide archaeometry techniques to analyze the properties of materials, even in the extreme case of demolition. In any case, the integral study of the sociocultural systems linked to industrial housing contexts in Malaga is still a task to be achieved and it is expected that this work can draw attention to this relatively less-attended topic.

Regarding archaeometry, while so far this analysis is case-based and somehow more oriented to archaeometallurgy, it can constitute a starting point to generate comparative studies of industrial archaeological materials in Malaga, present in architecture or other kind of artifacts. Metals can be expanded to other Fe- or Cu-based alloys, and some samples should be preserved for further, more detailed studies. Other materials such as bricks, mortars, etc. could also be characterized and collected for the same purposes. However, such a goal is still an initial idea because industrial metals and other materials are less studied archaeologically in the city and continue to disappear from the context, sometimes without leaving any trace in the scientific literature. Once achieved, this kind of data and sample banks could lead to a better understanding of industrial archaeological processes,

not only technically but also socially. Further comparative analysis about specific chemical compositions and crystallography might lead to a better diachronic and spatial understanding of manufacturing, commerce, and other still unrevealed economic or technological processes in the city.

7. Acknowledgements

This research was funded by the European Union – NextGenerationEU through a María Zambrano contract (Id 20118) and it is part of the project “Underground Built Heritage as a Catalyser for Community Valorisation” (Cost Action CA18110).

References

- Aburamadan, R., Trillo, C., Udeaja, C., Moustaka, A., Awuah, K. G., & Makore, B. C. (2021). Heritage conservation and digital technologies in Jordan. *Digital Applications in Archaeology and Cultural Heritage*, 22, e00197. <https://doi.org/10.1016/j.daach.2021.e00197>
- Aeropuertos Españoles y Navegación Aérea. (2022). *Estadísticas de tráfico aéreo*. <https://www.aena.es/es/estadisticas/inicio.html>
- Andalusian Government. (2022). *Catálogo General del Patrimonio Histórico Andaluz*. <https://acortar.link/JyeORl>
- Angelcos, N., & Méndez, M. L. (2017). Struggles against territorial disqualification: mobilization for dignified housing and defense of heritage in Santiago. *Latin American Perspectives*, 44(3), 100-112. <https://doi.org/10.1177/0094582X16682757>
- Ashish Ganju, M. N. (2016). Documentation and conservation of vernacular architecture: conservation and continuity. *International Journal of Environmental Studies*, 73(4), 484-490.
- ASTM. (2022). *ASTM International - ASTM A247-16A - Standard Test Method for Evaluating the Microstructure of Graphite in Iron Castings | Engineering360*. <https://standards.globalspec.com/std/3860942/ASTM%20A247-16a>
- Athens Charter. (1931). *The Athens Charter for the Restoration of Historic Monuments*. First International Congress of Architects and Technicians of Historic Monuments.
- Barrera-Fernández, D. (2021). *Málaga: Urbanismo, Turismo y Patrimonio*. Tirant Lo Blanch.
- Barrera-Fernández, D., & Hernández-Escampa, M. (2017). Spatial analysis of tourist activities and services in the historic city: The cases of Malaga and Plymouth. *European Journal of Geography* 8(1), 139-160.
- Caballero Monrós, E. (1967). *La capital de la provincia de Málaga y su futuro*. Gobierno Civil de Málaga.
- Carpenter, L. B., & Prentiss, A. M. (2022). *Archaeology of Households, Kinship, and Social Change*. Routledge.
- Carter, A. K. (2022). Building from the Ground Up: The Archaeology of Residential Spaces and Communities in Southeast Asia. *Journal of Archaeological Research*, 09170-4, 1-54. <https://doi.org/10.1007/s10814-021-09170-4>
- Cerda, E. (1892). *Plano anunciador de Málaga*. Instituto de Estadística y Cartografía de Andalucía. IECA1988015138. Signatura del original: Ministerio de Educación, Cultura y Deporte, Biblioteca Nacional (Madrid) - M. XLII/602.
- Choi, B. H. (2012). Reconsideration of the Athens Charter (1931). *Journal of architectural history*, 21(4), 25-36. <https://doi.org/10.7738/JAH.2012.21.4.025>
- Collini, L., Nicoletto, G., & Konečná, R. J. M. S. (2008). Microstructure and mechanical properties of pearlitic gray cast iron. *Materials Science and Engineering: A*, 488(1-2), 529-539. <https://doi.org/10.1016/j.msea.2007.11.070>
- Dell'Unto, N., Leander, A. M., Dellepiane, M., Callieri, M., Ferdani, D., & Lindgren, S. (2013). *Digital reconstruction and visualization in archaeology: Case-study drawn from the work of the Swedish Pompeii Project*. 2013 Digital Heritage International Congress (DigitalHeritage) (Vol. 1, pp. 621-628). IEEE.
- DeSilvey, C., & Harrison, R. (2020). Anticipating loss: rethinking endangerment in heritage futures. *International Journal of Heritage Studies*, 26(1), 1-7. <https://doi.org/10.1080/13527258.2019.1644530>
- Dirección General de Bellas Artes. (1985). *Resolución de 18 de julio de 1985, de la Dirección General de Bellas Artes, por la que se ha acordado tener por incoado expediente de declaración de Conjunto Histórico-artístico a favor de Málaga*. Boletín Oficial de la Junta de Andalucía nº 76 de 2 de agosto de 1985.
- Fundación CIEDES. (2022). *Málaga en cifras*. <https://acortar.link/5DOT1z>
- García Bujalance, S., Barrera-Fernández, D., & Scalici, M. (2019). Touristification in historic cities. Reflections on Malaga. *Revista de Turismo Contemporáneo*, 7(1), 93-115. <https://doi.org/10.21680/2357-8211.2019v7n1ID16169>
- General-Toro, P., Bordalo, R., Moreira, P. R., Vieira, E., Brunetti, A., Iannaccone, R., & Bottaini, C. (2021). Art Casting in Portuguese 19th Century Industrial Foundries: A Multi-Analytical Study of an Emblematic Copper-Based Alloy Monument. *Heritage*, 4(4), 3050-3064. <https://doi.org/10.3390/heritage4040170>
- González Edo, J. (1970). *Conjunto Histórico-artístico a favor de San Felipe Neri, Instituto "Vicente Espinel" y casas contiguas*. Archivo Histórico Provincial de Málaga. Sección González Edo 14.020.
- González Edo, J. (1944). *Proyecto de obras para reconstrucción del patio central del palacio árabe*. 1944. Archivo Histórico Provincial de Málaga. Sección González Edo 14.022.
- Graeber, D., & Wengrow, D. (2021). *The dawn of everything: A new history of humanity*. Penguin.
- Hodder, I., & Renfrew, C. (1982). *Symbols in action: ethnoarchaeological studies of material culture*. Cambridge University Press.
- Holtorf, C. (2015). Averting loss aversion in cultural heritage. *International Journal of Heritage Studies*, 21(4), 405-421. <https://doi.org/10.1080/13527258.2014.938766>
- Instituto de Estadística y Cartografía de Andalucía. (2022). *Andalucía pueblo a pueblo - Fichas Municipales*. Málaga. <https://acortar.link/DFCzO3>

- Instituto Nacional de Estadística. (2022). *Encuesta de ocupación hotelera*. <https://acortar.link/DAKp19>
- Kanashiro, M. (2004). Da antiga à nova Carta de Atenas– em busca de um paradigma espacial de sustentabilidade. *Desenvolvimento e Meio ambiente*, 9, 33-37.
- Lees, L. (2012). The geography of gentrification: Thinking through comparative urbanism. *Progress in Human Geography*, 36(2), 155-171. <https://doi.org/10.1177/0309132511412998>
- Malaga City Council. (1872). *Alcaldía primera constitucional de esta ciudad. Ordenanzas*. Archivo Municipal de Málaga. Varios-Ordenanzas, legajo 2.631.
- Malaga City Council. (1878). *Ordenanzas municipales de la ciudad de Málaga*. Archivo Municipal de Málaga. Varios-Ordenanzas, legajo 2.631.
- Malaga City Council (2011). *Plan Especial de Protección y Reforma Interior del Centro de Málaga*. PAM-PEPRI (83) M.
- Malaga City Council. (1992). *Plan Especial de Protección y Reforma Interior del Centro de Málaga*. Plano de delimitación. Gerencia Municipal de Urbanismo, Obras e Infraestructuras.
- Malaga City Council. (2000). *Plan Especial de Protección y Reforma Interior Perchel Sur*. PA-P.13 (97).
- Malaga City Council. (1999). *Plan Especial de Reforma Interior Trinidad-Perchel*. Modificado y refundido PAM-R.4.
- Malaga City Council. (1983). *Plan General de Ordenación Urbana*.
- Malaga City Council. (1948). *Plan General de Ordenación*. Aprobado por la Comisión Superior de Ordenación Urbana de Málaga el 1 de diciembre de 1948. Archivo Municipal de Málaga. Biblioteca de Málaga 67/04 and Archivo Histórico Provincial de Málaga. Sección González Edo caja 133.
- Malaga City Council. (1924). *Plan General de Reformas de la Ciudad*. Archivo Municipal de Málaga. Biblioteca de Málaga 27/82.
- Malaga City Council. (1929). *Proyecto de ensanche de Málaga*. Archivo Municipal de Málaga. Acuerdos de Pleno vol. 332 y 333.
- Malaga City Council. (1876). *Proyecto de ordenanzas municipales de construcción de Joaquín de Rucoba*. Cap. 2 Ornato. Archivo Municipal de Málaga. Varios-Ordenanzas, legajo 2.631.
- Málagaport. (2022). *Estudios e informes*. <https://www.malagaport.eu/estudios-e-informes/>
- Mileto, C., Vegas, F., Soriano, L. G., & Cristini, V. (Eds.). (2014). *Vernacular architecture: Towards a sustainable future*. Crc Press.
- Moss, J. (2016). *Conservation of buildings from the recent past: an investigation into England's legacy of post-war social housing and its heritage value*. [Doctoral dissertation]. University of Leicester. <https://acortar.link/PdYctZ>
- Niglio, O. (2009). Conservation and actuality in ancient environments. From the 1931 Athens Charter to the 2008 Bethlehem Charter. *EDA, Esempi di Architettura*, 1(7), 31-41.
- Observatorio del Transporte y la Logística en España. (2022). *Número de pasajeros de crucero por Autoridad Portuaria, por operación*. <https://apps.fomento.gob.es/bdotle/visorBDpop.aspx?i=330>
- Olukoya, O. A. (2021). Framing the Values of Vernacular Architecture for a Value-Based Conservation: A Conceptual Framework. *Sustainability*, 13(9), 4974. <https://doi.org/10.3390/su13094974>
- Ortiz Barili, P. (1945). *Reconstrucción de la Alcazaba. Una excursión y unas impresiones*. La Unión Mercantil.
- Ozomek, A. (2011, June 26). *Geografías del desastre: expolio del BIC Conjunto Histórico Artístico del centro de Málaga*. Edificios: paisaje urbano patrimonio BIC Centro Histórico Málaga. <https://acortar.link/CG2QUy>
- Pendlebury, J., Townshend, T., & Gilroy, R. (2016). Social housing as heritage: The case of Byker, Newcastle upon Tyne. In L. Gibson, & J. Pendlebury (Ed.), *Valuing historic environments* (pp. 193-214). Routledge.
- Pino, E. (2020). *Historia General de Málaga*. Almuzara.
- Rosique Cañas, J. A. (2017). El Centro Histórico de la megalópolis ingobernable: patrimonialización, turistificación y fachadismo del territorio. In F. De Alba (Ed.), *Las Paradojas de la Megalópolis: Un Debate a Diferentes Voces* (pp. 87-110). Centro de Estudios Sociales y de Opinión Pública, Cámara de Diputados.
- Steadman, S. R. (1996). Recent research in the archaeology of architecture: Beyond the foundations. *Journal of Archaeological Research*, 4(1), 51-93. <https://www.jstor.org/stable/41053111?seq=1>
- Valverde y Álvarez, E. (1888). *Guía del antiguo reino de Andalucía*. Imprenta de Fernando Cano y Domingo de Val. Archivo Municipal de Málaga. Biblioteca de Málaga 6/90.
- Vora, S. (2016, August 17). A Cultural Hub Takes Form in Málaga. *The New York Times*. <https://www.nytimes.com/2016/08/21/travel/malaga-spain-beach-holidays.html>